The Status of NHTSA's ESC Research

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Effectiveness of Electronic Stability Control for Preventing Crashes

ESC Effectiveness

- Multiple studies have been conducted looking at ESC effectiveness
  - Europe
  - Japan
  - United States
    - Two studies released in 2004

DaimlerChrsyler

- **German crash data**
  - **German Government Statistics Office (Statistischen Bundesamtes)**
  - **1999/2000 data compared to 2000/2001**
    - **Newly registered Mercedes vehicles**
    - **ESC standard equipment for MY1999**
  - **Estimates based on statistical analyses**
    - **15% reduction in total accidents**
    - **30% reduction in single vehicle accidents**
  - **Reductions in side-impacts, rollover crashes, and average injury severity**

Swedish Nat. Road Administration (Tingvall, et al.)

- **Swedish crash data**
  - Police reported accidents with at least one injured person
  - Accidents occurred during 2000 to 2002
  - Cars of similar/identical make model were used; 1998 to 2003 model years
- **ESC effectiveness estimates based on statistical analyses**
  - Dry roads: No significant effect
  - Wet roads: At least a 7.8% reduction*
  - Snow / Ice: At least a 12.1% reduction*
- **Most significant accident reduction observed for large cars (both front- and rear-wheel drive), especially on low-mu surfaces**

**Lower bound of the 95% confidence limit*

European Accident Causation Survey (Sferco, et al.)

- Potential ESC effectiveness based on statistical analyses of EACS data (i.e., the “opportunity” for ESC to improve safety)
- EACS contains data from approximately 1674 crashes in 5 European countries from 1995 to 1999
- Expert EACS investigators believe the presence of ESC could have improved the outcome of many accidents investigated
  - Injury accidents: 18%
  - Fatal accidents: 34%
- If accident causation was “loss of vehicle control”, the benefits of ESC are expected to be even more apparent
  - Injury accidents: 42%
  - Fatal accidents: 67%

Toyota
(Aga, et al.)

- **Japanese crash data**
  - **Compiled by the Institute for Traffic Accident Research and Data Analysis (ITARDA)**
  - **3 popular Toyota passenger cars were considered**
- **Estimates based on statistical analyses**
  - **35% reduction in single car accidents**
  - **30% reduction in head-on collisions with other vehicles**
  - **35% reduction in casualties per year (for single car crashes and head-on collisions)**
- **ESC effectiveness appears to be highest in the range of approximately 40 - 100 kmph (25 – 75 mph)**

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- **Examined single vehicle crashes**
  - Limited number of higher end vehicles
- **Two sources of data**
  - State data for all crash severities for five states (1997 – 2002)
  - FARS data (1997 –2003)
- **All severities of single vehicle crashes reduced**
  - Passenger cars: 35%
  - Sports Utility Vehicles: 67%
- **Fatal single vehicle crashes reduced by:**
  - 30% for passenger cars
  - 63% for Sports Utility Vehicles

Insurance Institute for Highway Safety

- Calculated fatal crash risk per registered vehicle for vehicles with ESC standard versus those with no ESC or ESC optional
- Found that:
  - Fatal single vehicle crash risk reduced by 56%
  - Multi-vehicle fatal crash risk reduced by 17%
  - Risk for all fatal vehicle crashes reduced by 34%
- If ESC present on all light vehicles, it could
  - Prevent 800,000 single vehicle crashes per year
  - Saving 7,000 lives per year

ESC Effectiveness - Summary

- **Multiple studies in several countries using different data sets and methodologies have all found:**
  - **Substantial reduction in single vehicle crashes due to ESC**
    - **Typically about a 30% reduction**
  - **Installation of ESC on all light vehicles should prevent many fatal crashes each year**

How Does Electronic Stability Control Prevent Crashes?

How ESC Helps

- Prevention of Untripped Rollovers
  - Test using NHTSA Fishhook
  - ESC can be tuned to prevent two wheel lift in NHTSA Fishhook
    - Not all tunings will prevent untripped rollover
    - Need aggressive front wheel braking to prevent rollover
  - Only small number of untripped rollovers

How ESC Helps

- **Prevention of Transient Oversteer**
  - **Intervention combats excessive yaw**
    - **Test using variant of single sine steer**
    - **Will discuss test in greater detail later**
  - **Part of benefit comes from slowing vehicle down**

Example of Transient Oversteer

2004 Volvo XC 90

ESC Disabled

SWA = 130 degrees

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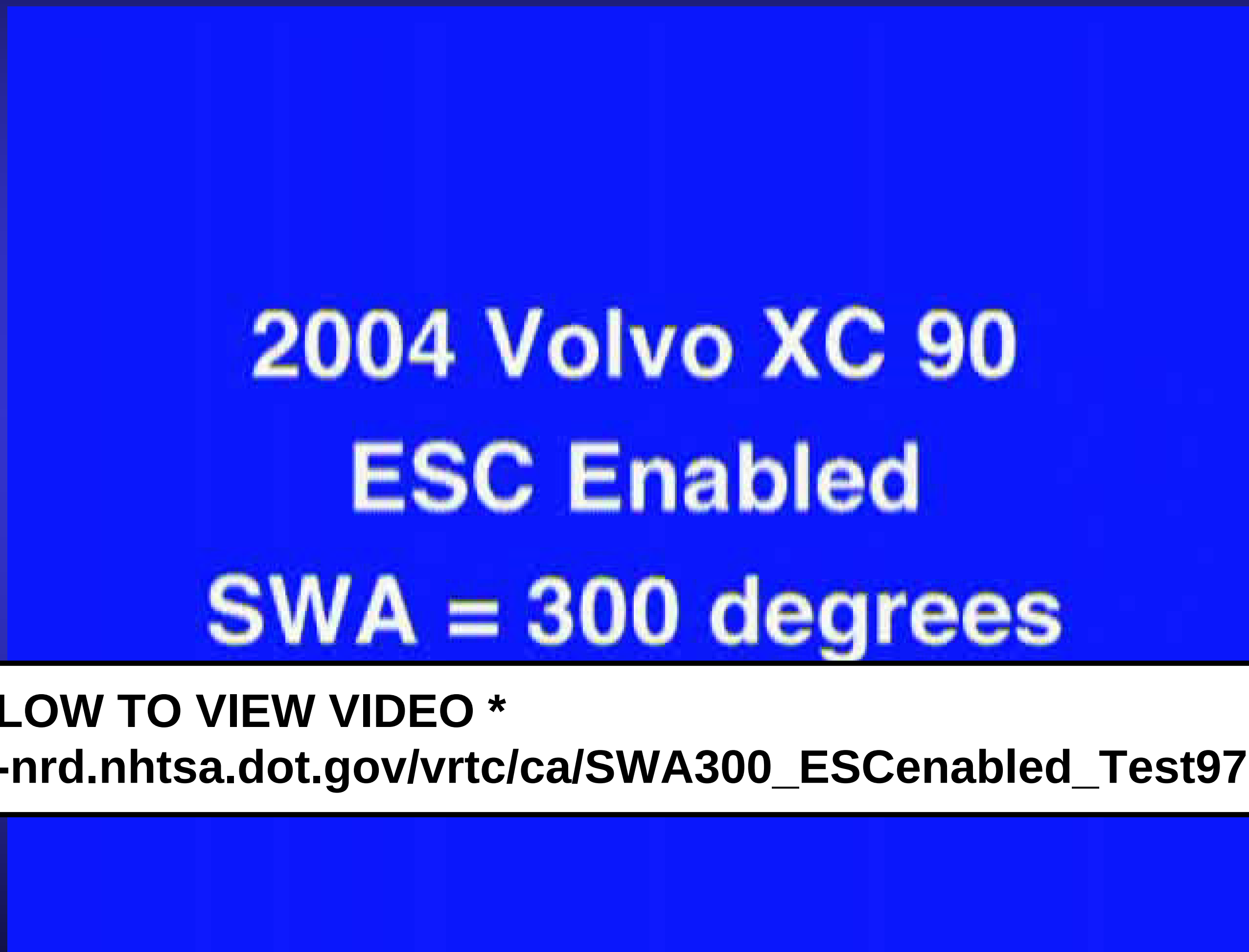
http://www-nrd.nhtsa.dot.gov/vrtc/ca/SWA130_ESCdisabled_Test984_DIVX.avi

Effect of ESC



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http://www-nrd.nhtsa.dot.gov/vrtc/ca/SWA300_ESCenabled_Test979_DIVX.avi

How ESC Helps

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- **Prevention of Transient Oversteer**
  - **Thought to be important mechanism for prevention of crashes**
    - **Approximately 25% of fatal single vehicle crashes believed to be due to transient oversteer**
    - **If ESC is preventing 30% of fatal single vehicle crashes, and transient oversteer is only responsible for 25%, some other mechanism must be at work**

How ESC Helps

- Prevention of Excessive Transient Understeer
  - Do not know how to test for excessive transient understeer
    - Plan to develop test in future
  - Thought to be important mechanism for prevention of crashes

How ESC Helps

- **Can Improve Brake Performance**
  - **Improved adhesion utilization**
  - **Pre-charging of brake system**
  - **Benefits not yet well understood**

Current NHTSA ESC Research Program

Program Objectives

- **Develop test to ensure that vehicle does not go out of control (spinout) due to transient oversteer**
  - **Develop pass/fail criteria**
- **Prevention of excessive transient understeer will be worked upon later**

Program Approach

- **Building on non-linear handling research performed by Alliance of Automobile Manufacturers**
- **NHTSA is collaboratively gathering data to improve proposed test to ensure that vehicle does not spinout due to transient oversteer**
  - **Refining pass/fail criteria**

Five Maneuvers
Performed With A Steering Machine

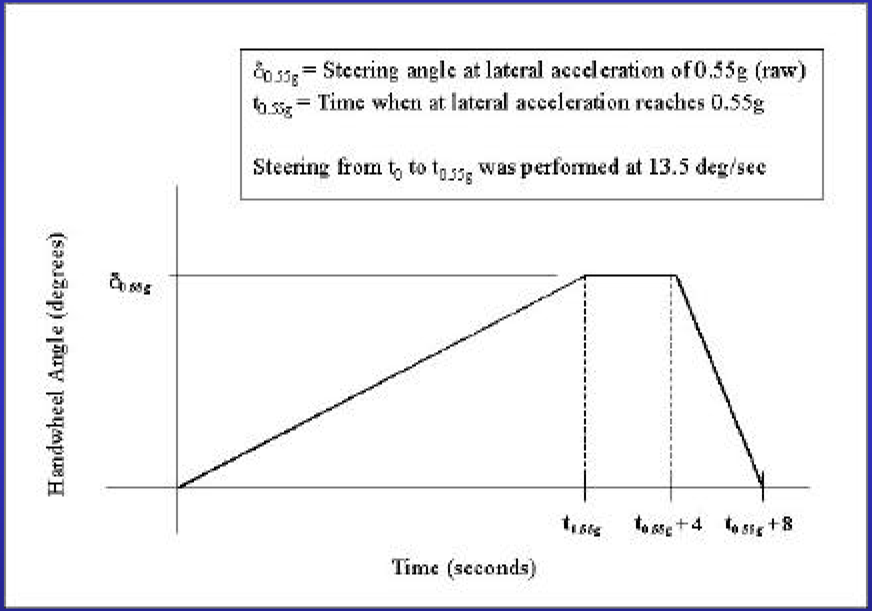
- **Slowly Increasing Steer** *(for characterization use only)*
- **0.7 Hz Sine with Dwell**
- **0.7 Hz Increasing Amplitude Sine**
- **500 deg/s Yaw Acceleration Steering Reversal**
- **500 deg/s Yaw Acceleration Steering Reversal w/Pause**

Test Conditions

- **ESC enabled and disabled**
- **Test surface**
  - **Dry, high-mu asphalt**
  - **Maneuvers initiated while vehicle is being driven up a 1% grade**
- **Nominal load**
  - **Driver**
  - **Instrumentation**
  - **Outriggers if vehicle is an SUV, pickup, van, minivan, station wagon, or crossover vehicle**

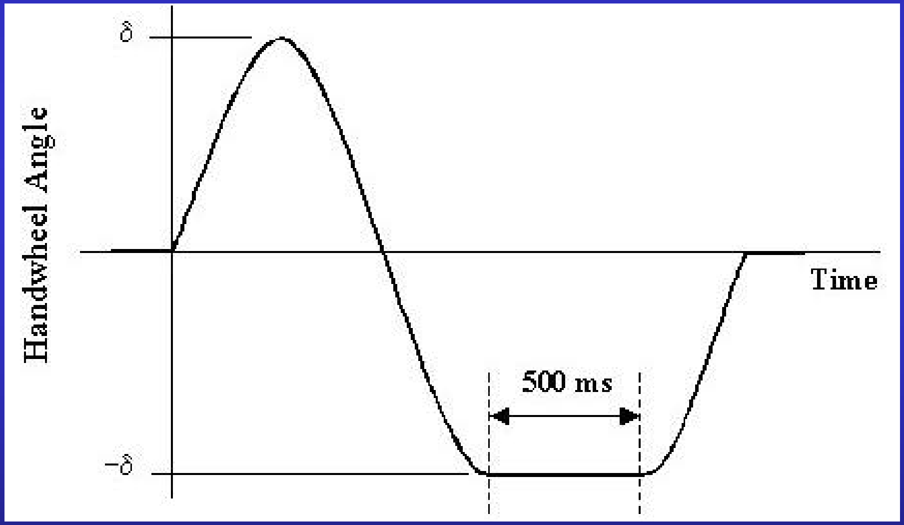
Maneuver Description
Slowly Increasing Steer

- **Low severity**
  - **Used for characterization only**
  - **Raw AY of 0.55g**
- **Provides the SWA at 0.3g**
  - **Data is required by all other maneuvers performed in this study**
  - **Must first be corrected for roll effects**
- **Driver attempts to maintain constant vehicle speed via throttle modulation**
  - **50 mph**



Maneuver Description
0.7 Hz Sine with Dwell

- **Steering frequency fixed at 0.7 Hz, but with a 500 ms pause after the 3rd quarter-cycle**
- **Severity increased with SWA**
  - **Increments of $1.0*d_{0.3g\ AY\ from\ SIS}$'**
  - **Lowest SWA: $1.5*d_{0.3g\ AY\ from\ SIS}$'**
  - **Highest SWA: 270 deg or $6.5*d_{0.3g\ AY\ from\ SIS}$, whichever is greater**
- **50 mph entrance speed**
- **Dropped throttle**



Maneuver Description
0.7 Hz Increasing Amplitude Sine

- **Steering of frequency first ½ cycle fixed at 0.7 Hz**
- **2nd ½ cycle amplitude is 1.3 times that of the 1st ½ cycle**
- **Duration of the 2nd ½ cycle is 1.3 times that of the 1st ½ cycle**
- **Severity increased with SWA**
  - **Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater**
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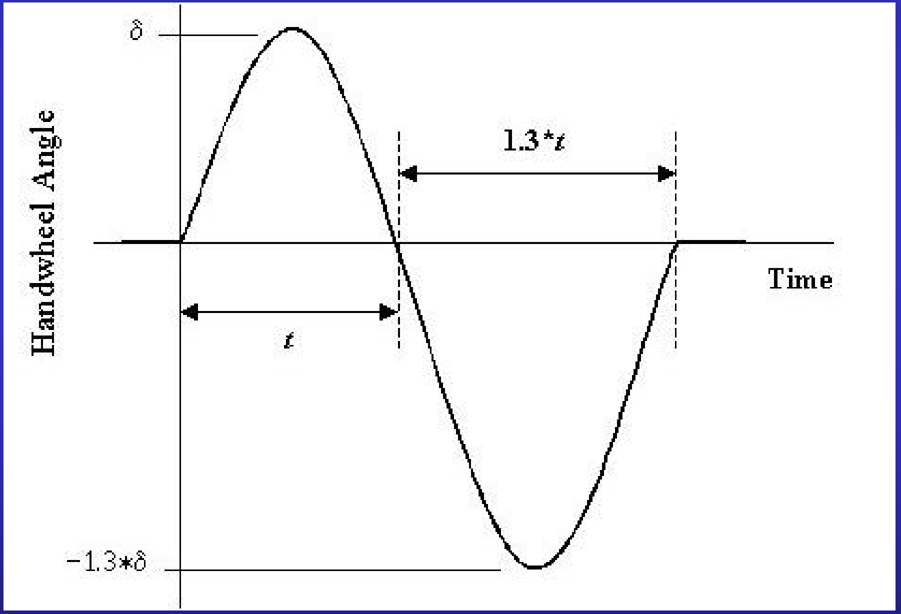

Maneuver Description
Yaw Acceleration Steering Reversal

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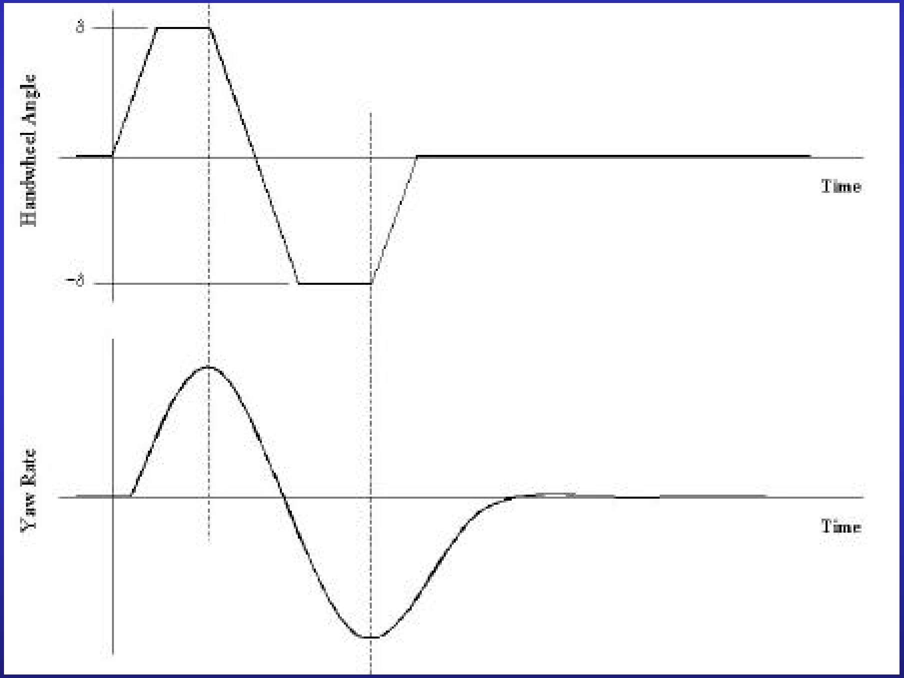
- **Maneuver adapts to the vehicle being evaluated rather than relying on one frequency**
- **Steering reversals both initiated at peak yaw rate**
- **Severity increased with SWA**
  - **Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater**
  - **500 deg/s ramp rates**



Maneuver Description
Yaw Accel Steering Reversal w/Pause

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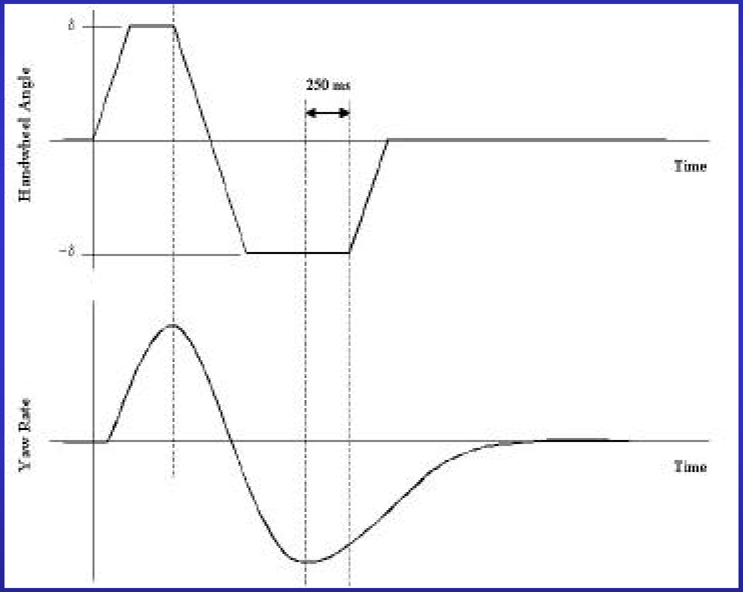
- **Maneuver adapts to the vehicle being evaluated rather than relying on one frequency**
- **1st steering reversal initiated at peak yaw rate, 2nd reversal at peak yaw rate + 250 ms**
- **Increased dwell after second yaw rate peak gives the vehicle more time to respond to the second peak SWA**
- **Severity increased with SWA**
  - **Increments of 1.0*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Lowest SWA: 1.5*$d_{0.3g\ AY\ from\ SIS}$,**
  - **Highest SWA: 270 deg or 6.5*$d_{0.3g\ AY\ from\ SIS}$, whichever is greater**
  - **500 deg/s ramp rates**



Direction of Steer

- Left-right tests precede those performed with right-left steering
  - 0.7 Hz Sine with Dwell
  - 0.7 Hz Increasing Amplitude Sine
  - 500 deg/s Yaw Acceleration Steering Reversal
  - 500 deg/s Yaw Acceleration Steering Reversal w/Pause
- Slowly Increasing Steer
  - Three left steer tests, followed by three right steer tests

Program Approach

- Each of these maneuvers has advantages and disadvantages
- Current work aimed at better understanding these for each maneuver

Vehicles Being Tested During 2005

Test Vehicles
(First Priority)

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Make	Model	Classification	ESC Availability
BMW	M5	High Performance Passenger Car	Standard
Cadillac	STS	Large Passenger Car	Standard
Chrysler	300 Limited	Large Passenger Car	Standard on all but base model
Mercedes	E-Class	Medium Passenger Car	Standard
Lincoln	LS	Medium Passenger Car	Optional
Porsche	911	High Performance Passenger Car	Optional
Scion	xB	Small Passenger Car	Standard
Subaru	Outback	Medium Passenger Car	Optional
Dodge	Sprinter	Van	Standard on some models
Ford	Freestar	Minivan	Optional
Pontiac	Montana SV6	Minivan	Optional on front-wheel drive model
Nissan	Frontier	Pickup	Optional
Toyota	Tacoma	Pickup	Optional
Toyota	Tundra	Pickup	Optional
Chevrolet	Avalanche	SUV	Standard for MY2005
Chevrolet	Suburban	SUV	Standard for MY2005
Jeep	Grand Cherokee 4x4	SUV	Optional
Honda	CR-V 4x4	SUV	Standard
Mitsubishi	Montero	SUV	Standard
Volkswagen	Touareg	SUV	Standard

Test Vehicles (Second Priority)

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Passenger Cars

Make	Model	Classification	ESC Availability
Acura	RL	Medium Passenger Car	Standard
Acura	TSX	Medium Passenger Car	Standard
Audi	A4 (AWD)	Medium Passenger Car	Standard
BMW	525i	Medium Passenger Car	Standard
BMW	Z4	High Performance Passenger Car	Standard
Buick	LaCrosse CXS	Medium Passenger Car	Optional
Cadillac	XLR	High Performance Passenger Car	Standard
Infinity	Q45	Large Passenger Car	Standard
Lexus	ES330	Medium Passenger Car	Standard
Mazda	RX-8	High Performance Passenger Car	Optional
Mercedes	SLK350	High Performance Passenger Car	Standard
Nissan	350Z	High Performance Passenger Car	Optional
Pontiac	Vibe	Small Passenger Car	Optional
Porsche	Boxster	High Performance Passenger Car	Optional
Saab	9-3	Medium Passenger Car	Standard
Toyota	Corolla	Small Passenger Car	Optional on "S" and "LE" models

Minivans, Pickups, and SUVs

Make	Model	Classification	ESC Availability
Honda	Odyssey	Minivan	Standard for MY2005
Nissan	Quest	Minivan	Optional
Toyota	Sienna	Minivan	Optional
Nissan	Titan	Pickup	Optional
BMW	X3	SUV	Standard
Ford	Explorer 4x4	SUV	Standard for MY2005
Hummer	H2	Large SUV	Standard for MY2006
Hyundai	Tucson	SUV	Standard
Infinity	QX45	Large SUV	Standard
Kia	Sportage	SUV	Optional
Land Rover	Land Rover	SUV	Standard
Lexus	RX330	SUV	Standard
Mercedes-Benz	M-class (MY2006)	SUV	Standard
Nissan	Armada	SUV	Optional

Requested Data

- **For each test performed:**
  - **Final heading angle (with respect to initial path)**
  - **Percent of peak yaw produced at t_0 + 1.0**
  - **Maximum lateral displacement produced**
  - **Longitudinal displacement from initiation of steering input to maximum lateral displacement**
  - **Was two-wheel wheel lift observed?**
- **Maximum steering wheel angle**
- **Data from "First Priority" vehicles desired by May 16, 2005**

Pass/Fail Criteria

- Spinout must not occur
  - Need definition of spinout
- Vehicle must still be responsive
  - Must achieve a minimum lateral displacement during test
    - How much lateral displacement?

What is a "Spinout"

- As far as I know, there is no generally accepted, quantitative definition
- People generally know spinout when they see it
- However, there are some vehicles/cases which are not clear

What is a “Spinout”

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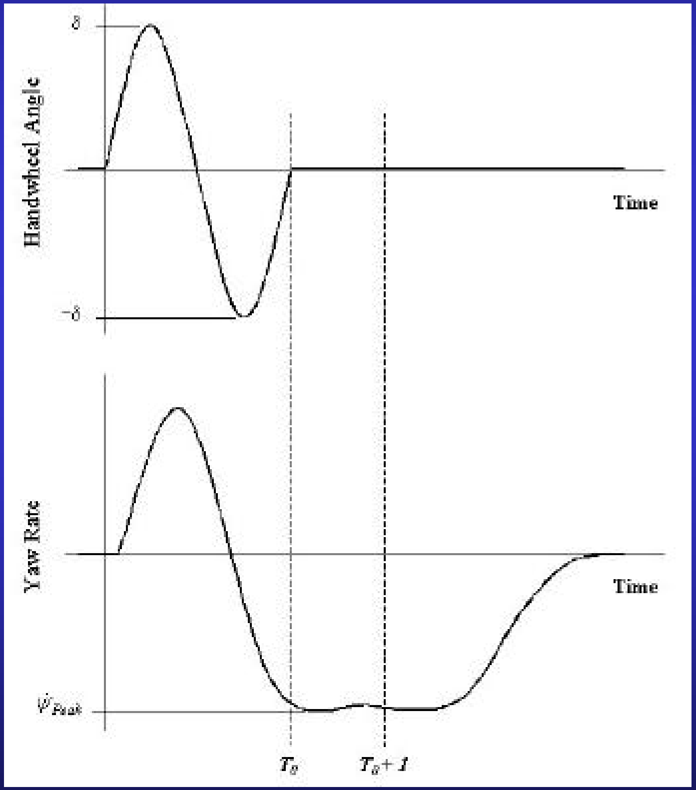
What is a “Spinout”
Preliminary NHTSA Definition

$$Percent\ \dot{y}_{Peak} = 100 * \left(\frac{\dot{y}(t)}{\dot{y}_{Peak}} \right)$$

$$Set\ t = t_0 + 1$$

$$Spinout\ occurs\ if\ \ Percent\ \dot{y}_{Peak} \geq 60\%$$



What is a "Spinout"

- Other people/organizations are developing alternative definitions of spinout
  - NHTSA welcomes alternate definitions!
- Will pick the best, most robust definition from among those suggested

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NHTSA hopes to have down-selected (at least, internally) to one test maneuver and to have better pass/fail criteria by July 1, 2005

Additional Information on NHTSA's Research

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- **ESC Docket**
  - **http://dms.dot.gov/search/searchFormSimple.cfm**
  - **Number 19951**
- **VRTC ESC Website**
  - **http://www-nrd.nhtsa.dot.gov/vrtc/ca/esc.htm**